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Report to Congress on Indoor Air Quality
Executive Summary and Recommendations

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Report to Congress on Indoor Air Quality

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This is a three volume report plus executive summary with recommendations that fulfills the reporting requirement of Title IV Section 403(e) of the Superfund Amendments and Reauthorization Act of 1986. The report contains a description of the research and program activities in Federal agencies; a comprehensive overview of the current level of knowledge and uncertainties associated with the issue of indoor air quality; and an identification of the major gaps and research needs in indoor air quality.

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of the

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U.S. Environmental Protection Agency

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TABLE OF CONTENTS

EXECUTIVE SUMMARY AND RECOMMENDATIONS

VOLUME I: FEDERAL PROGRAMS ADDRESSING INDOOR AIR QUALITY

I. Introduction

A. Purpose..... 1
B. Organization..... 1
C. Background..... 1

II. EPA Indoor Air Activities

A. Policy and Program Development Activities under Title IV.. 3
   1. Policy Development
   2. Information Dissemination
   3. Coordination
B. Research and Development Activities under Title IV..... 16
C. EPA Regional Office Activities..... 22
D. Addressing Indoor Air Quality at EPA's Headquarters Complex..... 22
E. Actions to Address Specific Problem Pollutants..... 25
   1. Radon..... 25
   2. Asbestos..... 37
   3. Environmental Tobacco Smoke..... 42
   4. Formaldehyde..... 44
   5. Chlorinated Solvents..... 45
   6. Pesticides..... 46

III. Activities Conducted by other Federal Agencies

A. Consumer Product Safety Commission 48
B. Department of Energy 53
C. Department of Health and Human Services 61
D. General Services Administration..... 68
E. Tennessee Valley Authority 69
F. Occupational Safety and Health Administration 73
G. Department of Transportation 74

Appendix

VOLUME II: ASSESSMENT AND CONTROL OF INDOOR AIR POLLUTION

I. Assessing the Health and Economic Impacts of Indoor Air Pollution

Chapter 1. Building Systems & Factors Affecting Concentrations and Exposures..... 1-1
Chapter 2. Significant Pollutants, Sources, and Health Effects.....2-1

Chapter 3. Measuring and Modeling Indoor Air Pollution..... 3-1
Chapter 4. Health Impacts..... 4-1
Chapter 5. Economic Impacts of Indoor Air Pollution..... 5-1

II. Controlling Indoor Air Pollution

Chapter 6. Methods and Strategies of Control..... 6-1
Chapter 7. Existing Indoor Air Quality Standards..... 7-1
Chapter 8. Federal Authorities Applicable to Indoor Air Quality..... 8-1
Chapter 9. Indoor Air Pollution Control Programs..... 9-1
Chapter 10. Indoor Air Quality Policy Issues.....10-1

VOLUME III: INDOOR AIR POLLUTION RESEARCH NEEDS STATEMENT

I. Overview of Indoor Air Pollution Research Needs

A. Purpose of the Indoor Air Research Program..... 1
B. The Indoor Air Research Setting..... 2
C. Radon..... 4
D. Summary of Research Needs..... 5

II. Research Needs

A. Risk Assessment..... 11
B. Exposure Assessment and Modeling Needs..... 15
C. Source-Specific Needs..... 18
D. Control Techniques..... 35
E. Building System Needs..... 38
F. Crosscutting Research..... 40
G. Technology Transfer..... 41

III. Additional Reading..... 43

EXECUTIVE SUMMARY

INTRODUCTION AND RECOMMENDATIONS

Title IV of the Superfund Amendments and Reauthorization Act of 1986 (SARA) requires the Environmental Protection Agency to establish a research program with respect to radon gas and indoor air quality and to disseminate information on indoor air quality problems and solutions. EPA is specifically required under Section 403(e) to submit a report to Congress describing the activities carried out under SARA Title IV and making such recommendations as appropriate.

This three volume report is designed to fulfill the reporting requirement of Section 403(e) as well as to provide Congress and the public with an up-to-date report on the status of efforts in the United States and elsewhere to assess and control indoor air pollution problems. The three volumes of the report include:

Volume I -- Federal Programs Addressing Indoor Air Quality
Volume II -- Assessment and Control of Indoor Air Pollution
Volume III -- Indoor Air Pollution Research Needs Statement

At this time, indoor air research and policy programs have not sufficiently characterized indoor air quality problems and solutions to be able to define the appropriate long-term Federal role regarding the need for, or appropriateness of, regulatory approaches to indoor air quality problems. Nevertheless, sufficient evidence exists to conclude that indoor air pollution represents a major portion of the public's exposure to air pollution and may pose serious acute and chronic health risks. This evidence warrants an expanded effort to characterize and mitigate this exposure. Consequently, EPA makes the following recommendations:

1. Research to better characterize exposure and health effects of chemical contaminants and pollutant mixtures commonly found indoors should be significantly expanded.

Although EPA is beginning to devote greater effort to characterizing non-cancer health effects from various exposure routes, information on exposure in homes and buildings is limited to a very few pollutants and groups of pollutants. In addition, virtually nothing is known about cancer and non-cancer health effects due to low level respiratory exposures to multiple chemical contaminants. An expanded research program in this field is needed to help characterize causes and solutions to the "sick building syndrome" and to investigate emerging health issues such as multiple chemical sensitivity.

2. A research program to characterize and develop mitigation strategies for biological contaminants in indoor air should be developed.

EPA's historical experience in addressing environmental hazards has been predominantly focused on chemical contaminants. However, biological

contaminants in indoor air are predominantly responsible for known building-related illnesses, which include Legionnaires disease and hypersensitivity pneumonitis, and have been increasingly associated with poor hygienic and maintenance practices in buildings. While both the National Institutes for Occupational Safety and Health (NIOSH) and the Consumer Product Safety Commission (CPSC) have active research underway, the lack of EPA participation limits the scope and magnitude of the effort.

3. Research to identify and characterize significant indoor air pollution sources and to evaluate appropriate mitigation strategies should be significantly expanded.

Source control is the most effective control option when major sources can be identified and characterized, and it may be the only viable option in some situations. However, significant resources must be devoted to identifying and characterizing sources to enable EPA and other Federal agencies to take appropriate control actions under existing authorities or to advise the public of the health risks from specific sources and actions they can take to reduce risk. Furthermore, research into innovative control technologies, and evaluation of technologies developed by the private sector, including air cleaning technologies, should be significantly enhanced.

4. A program is needed to develop and promote, in conjunction with appropriate private sector organizations, guidelines covering ventilation, as well as other building design, operation, and maintenance practices for ensuring that indoor air quality is protective of public health.

EPA believes that an effective national program to control indoor air pollution will require the application of generic strategies involving provisions for adequate ventilation, and provisions to avoid problems through proper building design, operation and maintenance. This approach, combined with programs targeted to specific individual high risk sources and pollutants would provide a comprehensive, but feasible and cost effective, control strategy. EPA does not believe that a pollutant-by-pollutant approach encompassing target levels for individual pollutants would resolve the bulk of indoor air quality problems.

5. A program of technical assistance, and information dissemination, similar in scope to the Agency's radon program, is needed to inform the public about risks and mitigation strategies, and to assist state and local governments and the private sector in solving indoor air quality problems. Such a program should include an indoor air quality clearinghouse.

While EPA has joined the ongoing Federal and private sector efforts to disseminate information on indoor air quality, as our experience with radon has demonstrated, a program is needed that can keep pace with the needs of state and local governments, architects, building owners and managers, researchers, the medical and health communities, building occupants and the general public who are seeking reliable technical and non-technical information. A program to transfer knowledge and develop capabilities in the public and private sectors would include a variety of technical assistance and

information dissemination activities comparable to those developed to address the radon problem. An indoor air information clearinghouse is needed to enhance coordination and access to such information.

6. The Federal government should undertake an effort to characterize the nature and pervasiveness of the health impacts associated with indoor air quality problems in commercial and public buildings, schools, health care facilities, and residences, and develop and promote recommended guidelines for diagnosing and controlling such problems.

The available literature suggests that indoor air quality problems are pervasive in a wide spectrum of buildings, but the prevalence of such problems, the nature of their sources, and the amount of human exposure attributable to these sources remains virtually unknown. However, an increasing number of complaints are being registered to government agencies, and a growing number of private sector firms are attempting to respond to a rapidly emerging market for diagnostic and mitigation services. A major study is needed to determine the scope and character of such problems, and to develop recommendations to guide and control the quality of diagnostic and mitigation services in the private sector.

SUMMARY OF VOLUME I -- FEDERAL PROGRAMS ADDRESSING INDOOR AIR QUALITY

In Volume I, the history of EPA's involvement in indoor air quality issues is briefly summarized, including early research initiatives, efforts to deal with specific pollutants such as asbestos, formaldehyde, radon, and pesticides, and EPA's relatively recent initiative to develop a comprehensive approach for characterizing and addressing indoor air quality issues. Specific actions such as the development of an indoor air quality policy and program, dissemination of information on indoor air issues, and coordination of the many activities underway within EPA, other Federal agencies, state and local governments and the private sector are described. Volume I contains a detailed status report on the Agency's Radon Action Program and other Agency programs related to indoor air quality. Reports from other Federal agencies involved in indoor air quality issues describe their historical, current, and anticipated roles in carrying out indoor air quality research and both regulatory and non-regulatory programs.

Indoor Air Program Development

Indoor air quality activities at EPA have expanded since 1986 and passage of SARA Title IV. Ongoing programs addressing individual problem pollutants continue under various legislative authorities and agency organizational units. However, in early 1986, in recognition of the need to establish a coordinated approach to addressing indoor air quality issues, a small indoor air staff, now the Indoor Air Division, was established in the Office of Air and Radiation (OAR). The Indoor Air Division coordinates the many indoor air quality issues being addressed by various EPA programs, establishes Agency indoor air policy, identifies and fills unaddressed program

needs, develops and disseminates information on indoor air quality, and provides policy direction to the indoor air research program.

Major activities of this Division during the past 18 months include initiatives to identify and analyze specific policy issues that will need to be resolved with respect to the long term Federal role in indoor air quality issues, development of mechanisms of coordination of government and private sector indoor air programs and activities, and active development of a wide spectrum of information on indoor air pollution problems and mitigation strategies. Major activities of the Indoor Air Division since passage of SARA Title IV include:

- o Sponsorship of a National Policy Forum on Indoor Air Quality to identify major policy issues and options with respect to the Federal role in addressing indoor air quality issues;

- o Initiation of a survey of private sector firms which offer indoor air quality diagnostic and mitigation services to the public in order to identify and evaluate the capability of the private sector to resolve indoor air quality problems in commercial and public buildings, residences, schools, hospitals, and day care facilities;

- o Development of a comprehensive status report on assessment and control of indoor air quality in the U.S., presented as Volume II of this report;

- o Participation in the Interagency Committee on Indoor Air Quality (CIAQ), the primary coordination vehicle for Federal indoor air quality activities;

- o Development and distribution, in cooperation with the Consumer Product Safety Commission, of a 32 page booklet for the general public titled The Inside Story: A Guide to Indoor Air Quality which describes residential and public building indoor air quality problems and solutions;

- o Publication of a 129 page Directory of State Indoor Air Contacts compiled by the Public Health Foundation under a cooperative agreement with EPA. The directory recognizes the decentralized nature of indoor air issues in the states by providing the public with the state agency contacts for various indoor air quality issues;

- o Publication of a series of fact sheets on indoor air quality issues. Fact sheets published in 1988 include Ventilation and Indoor Air Quality in Offices and Sick Buildings;

- o Preparation of a draft technical manual for building design engineers and architects which details indoor air pollution prevention and reviews diagnostic and mitigation considerations for new buildings;

- Development, in cooperation with several Department of Health and Human Services (DHHS) agencies, of a draft technical manual for policy makers on environmental tobacco smoke which describes the technical basis for smoking restrictions, as well as policy and technical options for implementing restrictions;

- Initiation of work on a self-paced introductory training course for state and local government personnel on indoor air quality, in preparation by the National Environmental Health Association under an interagency agreement between EPA and the Public Health Service.

Indoor Air Quality Research

Title IV of SARA mandates a comprehensive indoor air quality research and development program at EPA in order to identify, characterize, and monitor sources and levels of indoor air pollutants, to develop instruments for indoor air quality data collection, and to identify high risk building types. This research is performed by EPA's Office of Research and Development (ORD). The primary objective of ORD's indoor air pollution research program is to gain information in order to reduce exposure to indoor air pollutants known to cause health risks. The first step in achieving this goal is the identification and characterization of the health risks in the indoor environment. Once the risks have been evaluated, exposure reduction techniques must then be evaluated on the basis of their practicality, cost, and effectiveness. In order to reduce indoor air pollutant exposures that pose adverse health risks, EPA must also encourage the active participation of the public, industry, professional associations, and federal, state, and local governments. Technology transfer is an important part of the research program, and information on some health risks is sufficient to notify the public of the risks and mitigation procedures.

ORD's indoor air research program coordinates the research efforts of four EPA laboratories: the Health Effects Research Laboratory (HERL), the Atmospheric Research and Exposure Assessment Laboratory (AREAL), the Air and Energy Engineering Research Laboratory (AEERL) and the Environmental Criteria and Assessment Office (ECAO). Major accomplishments of the research program include:

- Completion of several major studies which were designed to assess the exposure of individuals to major indoor air pollutants. The Total Human Exposure Assessment Methodology (TEAM) studies on carbon monoxide, volatile organic compounds, and particulates utilized personal exposure monitors and time use pattern questionnaires and other techniques to directly measure total human exposure to air pollution and to apportion individual exposure among different microenvironments. These studies provided the first major evidence that indoor levels of many pollutants frequently exceed outdoor levels;

- Completion of an information assessment identifying the hazards of indoor environments which was submitted to Congress as part of EPA's Indoor Air Quality Implementation Plan in 1987. The document provides a

preliminary hazard identification of indoor pollutants and discusses current monitoring methods and mitigation techniques.

o Establishment and maintenance of the Indoor Air Pollution Reference Bibliography. This project is intended to be a complete list of all published information which pertains to indoor air pollution. Health effects, monitoring methods, exposure levels, and mitigation techniques are some of the key word categories that can be searched.

o Recent research indicates the possibility of additional adverse health effects from exposure to the emissions from kerosene and other unvented space heaters. New data on the complex emissions from these sources indicate that, in addition to elevated nitrogen dioxide and carbon monoxide levels, indoor particle levels may exceed outdoor standards, and these emissions include high sulfate and acidic ion concentrations. Similar concentrations have been reported to cause pulmonary irritancy in humans. Additional research will be conducted to verify and expand on these preliminary findings.

o Research devoted to characterizing emissions from materials has developed preliminary procedures for small chamber testing of emissions from building materials and consumer products such as moth repellents, particleboard, floor wax, dry cleaned fabrics, carpet, and office partitions. These studies provide information on the emission rates and composition of organic vapors over a wide range of conditions, and can be used to develop standard methods for emission testing of indoor materials by manufacturers.

o Research in a well-characterized test house has emphasized the study of pollutant sources, sinks, and transport in field settings. The research test house has been used to study indoor pollutant concentrations originating from moth crystals, caulking compounds, kerosene heaters, and cleaning solvents from dry cleaning. The test house is the validation step in indoor air pollution research. The results achieved in chamber studies can be verified in test house studies for use in generating a predictive model of indoor air pollution scenarios.

o Indoor air control studies have examined the effectiveness of activated carbon in air cleaning devices for the control of typical indoor concentrations of volatile organic compounds. This research has shown that activated carbon devices are ineffective in removing VOCs. The prediction of ozone generation from a wide range of electrostatic air cleaners is the subject of a second study.

o A compendium of indoor air measurement methods is under development to assist in the standardization of sampling and analysis methods for VOCs, SVOCs (semi-volatile organic compounds), nicotine, carbon monoxide, carbon dioxide, nitrogen dioxide, formaldehyde, particles, air exchange rates, and pesticides.

o ORD has made advances in modelling indoor air pollutants, which builds upon early work by the Lawrence Berkeley Laboratory. In collaboration with DOE and CPSC, EPA/ORD has supported at the National Institute of Standards and Technology (NIST, formerly NBS) the development of an advanced, mathematical multi-zonal model to predict indoor air pollution concentrations in large complex buildings. ORD has developed a more simplified indoor air quality model which has been validated using a research test home and is currently available. The effects of sources, sinks, and ventilation changes can be examined through these models, and will help researchers evaluate problems and solutions and aid in building design considerations.

o Indoor pollutant concentrations measured in ten public access buildings, including schools, homes for the elderly, and office buildings, indicate that newly constructed buildings may have levels of some VOCs as much as 100 times normal levels. These levels diminish rapidly during the first several months of the buildings' life. This study is of importance because these buildings may contain populations which are very sensitive to these pollutants (e.g. children and the elderly).

o Along with NIOSH, NIST, and DOE, EPA has initiated an investigation of complaints of indoor air pollution in the Library of Congress Madison building as well as at EPA's own headquarters complex. This study will include simultaneous measurement of both pollutant levels and ventilation rates, and the administration of an occupant survey questionnaire. ORD researchers have also provided ongoing support in the investigation of occupant complaints at the EPA Headquarters building (Washington, DC). This support has included taking air samples, testing the off-gassing of materials (carpeting and partitions), and reporting on the results from these studies to EPA management and employees.

o Health effects research has demonstrated that cotinine can be used as a biological marker of exposure to nicotine from environmental tobacco smoke (ETS), especially in children. A laboratory chamber study will soon be initiated to evaluate cotinine for ETS dosimetry.

o Research devoted to studying human responses to VOC mixtures has begun which will validate a study conducted in Denmark which demonstrated that exposures to mixtures of VOCs can produce behavioral and sensory irritant effects, even though each individual compound is below the known threshold for neurological effects. This study will help to evaluate one of the suspected causes of sick building syndrome.

o EPA has conducted a major study of non-occupational exposure to pesticides using the TEAM study approach. Preliminary data indicate that indoor exposure to pesticides is widespread, with as many as 10 different pesticides being detected in a single home. This research is of interest because these pesticides are used not only within the

residence, but includes pesticides used outdoors which have also been found to enter the home environment.

o As part of the Technology Transfer program, the Office of Research and Development also sponsored the Consumer Federation of America's Third National Indoor Air Quality Conference. This conference is held annually to provide a forum for an exchange of information and a discussion of the technical and policy implications of the causes and consequences of indoor air pollution.

Actions To Address Specific Problem Pollutants

RADON

In addition to describing EPA's research and program development activities on the broad indoor air quality front, Volume I of the report also provides summary reports of the on-going efforts of EPA to address specific problem pollutants. Most pertinent to SARA Title IV is the Radon Action Program, which seeks to address the risks from indoor exposure to naturally occurring radon. In 1985, EPA introduced this program to develop and disseminate information and expertise related to radon and encourage the development of state programs and private sector capabilities in these areas. The major elements and accomplishments of the Radon Action Program include:

1. Problem Assessment to determine the distribution and levels of radon exposures and, in cooperation with the Department of Energy (DOE), the associated health effects. Accomplishments include:

- o Standardization of radon measurement methods
- o National Survey of 2000-5000 homes
- o Assistance with State surveys
- o Development of geologic maps indicating potential high radon risk areas
- o Development of methods for predicting potential high risk areas

2. Mitigation and Prevention to develop methods for reducing radon levels in existing structures and for preventing radon entry in new construction. Accomplishments include:

- o Development of techniques for reducing and preventing elevated radon levels
- o Transfer of mitigation technologies to states and the private sector
- o Evaluation of the effectiveness of radon resistant construction features in new construction
- o Investigation of the incorporation of radon resistant construction techniques into building codes

3. Capability Development to develop the capacity within the states and the private sector to diagnose and remedy radon problems in homes. Accomplishments include:

- o Establishment of diagnosis and mitigation training course
- o Establishment of programs to evaluate radon measurement services

4. Public Information to inform the public about the health risks associated with radon exposure and methods for reducing those risks. Accomplishments include:

- o Development of citizen action guidelines
- o Preparation of numerous public information documents on radon
- o Presentations on radon given to hundreds of organizations
- o Education of health care workers
- o Examination of the effectiveness of risk communication activities

EPA is also participating in a number of important activities related to radon in addition to those conducted under the Radon Action Program. In accordance with the Safe Drinking Water Act (SDWA), EPA is working to develop a set of enforceable standards for radon and other radionuclides in drinking water. EPA is also working closely with a number of other Federal agencies to address the radon problem. These activities include a cooperative agreement with the Department of Energy (DOE) with respect to each agency's research role and providing assistance to agencies like the Department of Housing and Urban Development (HUD), National Park Service (NPS), and the Department of Defense (DOD) in developing their own radon programs. EPA and DOE also co-chair the Radon Workgroup of the Interagency Committee on Indoor Air Quality (CIAQ).

ASBESTOS

EPA's asbestos program predates SARA Title IV by several years. Since 1979, when EPA first instituted an asbestos technical assistance program, the asbestos program has grown into a major national program to reduce the risks to public health from exposure to asbestos. EPA's efforts to address asbestos problems encompass the full range of regulatory, grant, and technical assistance activities. While the primary focus of the asbestos program has been in the Nation's schools, the program has also begun to address asbestos problems in commercial and public buildings and homes.

The major activities of the asbestos program in reducing exposure to asbestos-containing materials in schools, described in Volume I of this report, include:

- o Promulgation of the Asbestos-Containing Materials in Schools Rule in October 1987;

- o Development of a model accreditation plan to provide for training and accreditation of persons who inspect school buildings, develop management plans or design or conduct response actions;

- o Implementation of the asbestos loan and grant program to provide financial assistance to schools with severe asbestos hazards and financial need and the Asbestos Inspection and Management Planning

Assistance Program (AIMPAP). These programs have provided more than $175 million in school assistance since 1985;

o Development and distribution of guidance documents for building owners and others responsible for carrying out asbestos abatement activities;

o Development and funding of five university asbestos information and training centers as well as four satellite training centers;

o Distribution of grants to States for certification, training and accreditation programs.

Activities to reduce exposure to asbestos-containing materials in commercial and public buildings include:

o Establishment of regional technical assistance outreach program, involving EPA asbestos coordinators and technical support staff;

o Submission to Congress in February 1988 of a report on the Public and Commercial Buildings Study, in which EPA estimated that 20 percent of commercial and public buildings (at least 700,000 buildings) contain friable asbestos;

o Completion of a major field study which compares airborne outdoor asbestos levels with prevailing indoor levels in 43 Federal buildings with asbestos-containing materials. An interim report on the results of the study indicates very low prevailing levels in Federal buildings and no statistical difference between indoor and outdoor levels, even in buildings with damaged asbestos-containing materials;

o Sponsorship of the Federal Asbestos Task Force (FATF), a working group of Federal agencies with asbestos control responsibilities; and

o Publication and distribution, in cooperation with CPSC, of the booklet Asbestos in the Home.

Other asbestos regulatory activities include:

o Proposed revision of the National Emissions Standards for Hazardous Air Pollutants (NESHAPS) for asbestos under Section 112 of the Clean Air Act:

o Issuance of a worker protection rule under Section 6 of the Toxic Substances Control Act (TSCA);

o A proposal, also under Section 6 of TSCA, to ban certain asbestos products and phase out others.

ENVIRONMENTAL TOBACCO SMOKE

Published reports of the Surgeon General and the National Research Council (NRC) of the National Academy of Sciences conclude that exposure to environmental tobacco smoke (ETS) (i.e., passive smoking) is a cause of lung cancer in healthy non-smokers and is responsible for both acute and chronic respiratory and other health impacts in sensitive populations, including children of smokers. Published risk estimates place ETS among the most harmful indoor air pollutants, and higher in risk than many environmental pollutants currently regulated by EPA.

Accordingly, EPA has established a research program on environmental tobacco smoke as well as a risk assessment and information program. These programs will enable EPA to provide the public with an understanding of the hazards of ETS as well as reliable methods for risk mitigation (e.g., establishment of smoking restrictions such as separately ventilated smoking areas). A number of EPA total exposure monitoring studies have shown that ETS is the dominant source of particulate matter in buildings where smoking is allowed, and that ETS contributes a significant fraction of carbon monoxide and volatile organic compounds (VOCs) -- including benzene -- exposures. Health studies by EPA's Health Effects Research Lab show that ETS contributes the bulk of mutagenic activity in indoor air. Among the activities currently underway:

- Continued research into the use of cotinine, a metabolite of nicotine, as a biological marker for ETS exposure so that an estimate of the dose received from exposure to ETS can be made;

- Evaluation of mutagenicity as a biological marker for ETS exposure;

- Continued studies of the exposure of children to ETS as well as participation in multi-agency ETS exposure studies;

- Development of a formal lung cancer risk assessment under EPA's Cancer Risk Assessment Guidelines;

- Development of a policy-maker's handbook and supporting reference manual on workplace smoking policies, in conjunction with the National Cancer Institute, the National Heart, Lung, and Blood Institute, the Office on Smoking and Health, and the Office of Disease Prevention and Health Promotion of the Public Health Service;

- Publication of a fact sheet on environmental tobacco smoke, as the fifth in a series of short publications on indoor air pollution issues.

FORMALDEHYDE

In 1984, EPA designated formaldehyde for priority attention under the provisions of Section 4(f) of TSCA. EPA's investigation is currently focused on developing the technical basis for decision making on the need for, and nature of, additional Federal regulations affecting formaldehyde emissions

from urea-formaldehyde (UF) pressed wood products (particleboard, hardwood plywood paneling, and medium density fiberboard). EPA has been studying the potential costs and residential air quality impacts of a range of possible controls on pressed wood products, including product emission standards, use limitations, product restrictions and labeling. This information will be used to determine whether or not an "unreasonable risk" exists. A decision on which actions EPA will take with respect to formaldehyde is likely to be made in 1989.

CHLORINATED SOLVENTS

The Interagency Integrated Chlorinated Solvents Project is an interagency work group chaired by EPA's Office of Toxic Substances with participation by seven major EPA offices, the Consumer Product Safety Commission (CPSC), the Occupational Safety and Health Administration, and the Food and Drug Administration (FDA). The Project is addressing the risks from four chlorinated solvents (methylene chloride, perchloroethylene, trichlorethylene, and 1,1,1-trichloroethane) in four use categories (dry cleaning, solvent cleaning, aerosols, and paint stripping). The Project is tasked with determining appropriate control options and developing regulatory options for use by the EPA Administrator. Options addressing risks from use of consumer products containing methylene chloride and/or perchloroethylene are expected to be presented to the EPA Administrator in mid-1989.

PESTICIDES

The Federal Insecticide, Fungicide, and Insecticide Act (FIFRA) provides EPA with the authority to control pesticide exposure by requiring that any pesticide must be registered with EPA before it may be sold, distributed or used in this country. As a pre-condition for registration, an applicant must be able to demonstrate that the pesticide in question will not cause "unreasonable adverse effects" (as defined by the Act) to people or the environment. When evidence arises that indicates that a registered pesticide product might cause unreasonable adverse effects, EPA may initiate a review process to determine if cancellation or some other regulatory action is warranted, based on a consideration of both the risks and benefits of the pesticide in question.

In recent years, EPA has taken a number of actions to protect the public from potentially unreasonable risks due to pesticide residues in indoor air. These actions include:

- A variety of measures which have resulted in the removal of the cyclodiene termiticides (aldrin, dieldrin, heptachlor, and chlordane) from the marketplace;
- Cancellation of the indoor fumigation use of lindane in 1985;
- A ban on all indoor uses of two wood preservatives, pentachlorophenol and creosote.

In addition to these regulatory actions, a number of other activities are being conducted under FIFRA with implications for indoor air quality. EPA has become increasingly concerned about the potential effects of so called "inert" ingredients which are frequently used in pesticide formulations as solvents or baits. While inerts are not toxic to the target pest, as are the active ingredients, some may cause health effects in humans. Accordingly, EPA began in 1988 to request additional health and environmental data from the registrants of 57 inerts known to have toxic effects. In 1987, EPA also decided to request data from registrants on the chronic toxicity of antimicrobials frequently used as cleaning and disinfecting agents -- pesticides which the agency heretofore only requested acute toxicity data. Currently, EPA is reviewing existing pesticide labeling conventions to determine if the Agency should modify its requirements in order to enhance the clarity and utility of label information to the pesticide user. Finally, the TEAM approach cited above under "Indoor Air Quality Research" is being expanded to include pesticides (the Non-occupational Pesticide Exposure Study).

Indoor Air Quality at EPA's Headquarters Complex

In 1988, EPA's concern over indoor air quality became somewhat more immediate as a significant number of EPA employees began complaining of health effects which many associated with an extensive renovation program at EPA's Waterside Mall complex, including the installation of new carpeting and partitions, as well as painting and other physical improvements. Volume I of the report briefly describes EPA's own indoor air quality problems and the steps that have been taken to characterize the quality of the indoor environment, identify contaminants, and minimize or eliminate contaminant sources.

Activities of Other Federal Agencies

A number of Federal agencies are actively involved in indoor air quality issues and participate with EPA on the Interagency Committee on Indoor Air Quality (CIAQ). In order to provide Congress with a complete picture of the Federal programs now addressing indoor air quality, Volume I contains program descriptions provided by several of these agencies detailing their involvement and activities in resolving indoor air quality problems. Many of the activities described by various agencies, including EPA, are part of a broad-based, coordinated Federal and private sector effort to address major aspects of the indoor air quality problem.

The Consumer Product Safety Act (CPSA) and the Federal Hazardous Substance Act provide the **Consumer Product Safety Commission (CPSC)** with regulatory authority over consumer products that may contribute to indoor air pollution. Since many of the sources of indoor air pollution are consumer products (e.g. household chemicals), CPSC plays a significant role in addressing indoor air pollution.

The **Department of Energy (DOE)** has played a major role in indoor air quality since the 1970s. The two primary DOE indoor air quality policy

goals are: 1) elimination of potential hazards to the public and environment from radioactive contamination remaining at facilities and sites previously used in the nation's atomic energy programs; and 2) development of information to ensure the maintenance of healthful indoor environments with continuing use of energy conservation measures in buildings. DOE's interests in indoor air quality are focused on research and development, the DOE Remedial Action Program, health risk assessment, and participation on the Interagency Committee on Indoor Air Quality. A significant portion of DOE's efforts in indoor air a e related to radon exposure and health effects research. Five DOE organizations are involved in indoor air quality activities:

--Office of Conservation and Renewable Energy (CE)
--Office of Energy Research (ER)
--Office of Nuclear Energy (NE)
--Office of Environment, Safety, and Health (EH)
--Bonneville Power Administration (BPA)

The **Department of Health and Human Services (DHHS)** is a major contributor to the identification and resolution of indoor air quality problems through several of its organizational components. The **National Institute for Occupational Safety and Health (NIOSH)** serves as the DHHS co-chair of the CIAQ and is the primary agency of the Federal government with extensive experience in conducting building investigations. Since 1971, NIOSH has conducted approximately 550 indoor air quality investigations under its Health Hazard Evaluation Program.

The DHHS agencies that participate in indoor air quality research or mitigation activities include:

- **Centers for Disease Control:**
  - --National Institute for Occupational Safety and Health (NIOSH)
  - --Center for Environmental Health and Injury Control (CEHIC)
  - --Center for Chronic Disease Prevention and Health Promotion (CCDPHP)
  - --National Center for Health Statistics (NCHS)

- **National Institutes of Health (NIH):**
  - --National Institute of Environmental Health Sciences (NIEHS)
  - --National Institutes of Allergy and Infectious Disease (NIAID)
  - --National Cancer Institute (NCI)
  - --National Heart, Lung, and Blood Institute (NHLBI)
  - --National Institute of Dental Research (NIDR)

- **Health Resources and Services Administration (HRSA)**

- **Agency for Toxic Substances and Disease Registries (ATSDR)**

Since the early 1980s, the **Tennessee Valley Authority (TVA)** has implemented an integrated indoor air quality program to provide public information and education, technical assistance to agencies and organizations,

and research and demonstration projects supporting the evaluations of its programs and policies.

The **Occupational Safety and Health Administration (OSHA)**, is charged under the Occupational Safety and Health Act with protecting the health of workers in the workplace. Recent interest in indoor air quality in non-industrial settings has prompted OSHA to begin development of guidance for its inspectors on identifying non-industrial indoor air quality problems.

The **General Services Administration (GSA)** is involved in a variety of indoor air quality activities related to its responsibilities to manage a significant portion of Federal buildings. GSA has implemented regulations to control smoking in GSA-controlled space. Radon, asbestos, and indoor air quality programs have also been developed and implemented.

A number of other government and quasi-government agencies conduct research or other activities which have significant indoor air quality implications. The **National Institute of Standards and Technology (NIST**, formerly the National Bureau of Standards) has done extensive work developing a comprehensive indoor air quality model and has contributed significant resources and expertise to a number of multi-agency research projects. The **National Institute of Building Science (NIBS)**, a quasi-governmental body created by Congress, works with the building industry to integrate into the building sciences measures that promote indoor air quality.

SUMMARY OF VOLUME II -- ASSESSMENT AND CONTROL OF INDOOR AIR POLLUTION

Volume II, **Assessment and Control of Indoor Air Pollution** presents information on the nature and magnitude of indoor air quality problems, on control methods, and on policies and programs in the public and private sectors. This volume addresses indoor air pollution from two perspectives. The first perspective examines indoor air pollution on a pollutant-by-pollutant basis, identifying key pollutants, sources, exposures, and risks. The second perspective is a broader building systems approach addressing indoor air pollution as a whole. This perspective is based on knowledge that the health, comfort and productivity of building occupants is greatly influenced by the design, operation and maintenance of buildings, and of the activity of building inhabitants.

Volume II is divided into two Parts. Part I, entitled *Assessing Health and Economic Impacts of Indoor Air Pollution*, characterizes building systems in the United States and their impact on indoor air pollutant levels, and assesses the nature and magnitude of the potential health risks and costs resulting from indoor air pollution. Part II, entitled *Controlling Indoor Air Pollution*, covers controls in terms of engineering and operational methods, as well as the legislative and policy instruments that are available and that may be used in both the public and private sector.

Part I begins with information on the U.S. building stock, and outlines those building factors that affect concentrations of indoor air pollutants.

Factors addressed include source emissions from building materials and appliances, the air exchange or ventilation rate, and various chemical and physical removal mechanisms. Building system inadequacies commonly identified in investigations of building air quality complaints are also discussed and include inadequate ventilation, contamination from indoor sources, reentrainment of indoor pollutants, contamination from exterior sources, and microbial problems.

Chapters 2 through 5 characterize the health and economic impact from indoor air pollution. In these chapters, major pollutants, sources, health effects, exposures, and risks are identified. Populations which may be particularly sensitive to indoor pollutants are addressed. The major pollutants are: radon, environmental tobacco smoke, biological contaminants, volatile organic compounds including formaldehyde and pesticides, polycyclic aromatic hydrocarbons (PAHs), asbestos, combustion gases including carbon monoxide and nitrogen dioxide, and particles.

The health effects identified for these pollutants cover the range of acute and chronic effects, and include eye, nose, and throat irritation and respiratory effects, neurotoxicity, kidney and liver effects, heart functions, allergic and infectious diseases, developmental effects, mutagenicity, and carcinogenicity. In addition to individual pollutants and their effects, recent findings on the effects of pollutant mixtures, as well as what is known concerning building related illnesses, sick building syndrome, and multiple chemical sensitivities are also discussed. The major conclusions to be drawn from this section of the report include:

- Biological contaminants are an important dimension of indoor air quality, can be the principal problem in some buildings, and can result in death, as in Legionnaire's disease, or serious infectious or allergic diseases.

- Additive or synergistic effects from multiple chemical contaminants, where the concentration of each individual compound is below its known health effect threshold.

- Sick building syndrome, building related illnesses, and multiple chemical sensitivity are issues of potentially great significance but are poorly understood.

In addition, health risks and economic impacts of indoor air pollution are quantified in chapters 3, 4 and 5 based on available literature. Several important conclusions emerge from this presentation:

- Risk estimates are not available for most pollutants, but available estimates for radon, ETS, and VOCs demonstrate that indoor air pollution is among the nation's most important environmental health problems.

- Environmental tobacco smoke is particularly toxic, estimated to account for a significant number of cancer and non-cancer mortality cases per year.

- The potential economic impact of indoor air pollution is quite high, and is estimated in the tens of billions of dollars per year. Such impacts include direct medical costs and lost earnings due to major illness, as well as increased employee sick days and lost productivity while on the job.

- Labor costs may be 10 to 100 times greater per square foot of office space than energy and other environmental control costs. Thus, from a profit and loss standpoint, remedial actions to improve indoor air quality where productivity is a concern are likely to be cost effective even if they require an expensive retrofit.

Part II of Volume II provides information on methods and strategies to control indoor pollution. The engineering and operational methods covered include source control, ventilation control, and air cleaning strategies. These strategies are discussed within the context of their import in developing the design, operation, and maintenance practices in buildings. Diagnostic protocols to anticipate and trouble-shoot indoor air quality problems are also discussed. Several important perspectives emerge from this discussion:

- Source control is the most direct and dependable control option, and may be the only effective control option when strong pollutant sources are present. However, where problems result from multiple sources, or where the sources or etiology of the problems are not known, source control in existing buildings may not be economically or technically feasible. In these cases, increased ventilation or air cleaning may be more appropriate controls.

- Individuals can exercise a high degree of control over their own indoor environment, particularly in residential settings, and thus reduce their exposures to many indoor pollutants at little or no cost. Control may be exercised through informed choices concerning the types of products and materials purchased and their use, proper care and maintenance of potential sources such as combustion devices, and appropriate balancing of indoor air quality and energy concerns in ventilation practices.

- Low outdoor air ventilation rates designed to conserve energy can result in significant indoor air quality problems. Adequate outdoor air ventilation is a necessary component to an effective air pollution control strategy, but adequate ventilation does not guarantee adequate indoor air quality.

- Air cleaning can complement but not replace the need for adequate outdoor air ventilation. Air cleaning technology is most readily applied to airborne particulates. Air cleaning devices are not designed to effectively remove gaseous contaminants and proper maintenance of the specialized devices designed to remove these pollutants may be cost-prohibitive. Air cleaning is most effective when integrated into the

central air circulation system. The effectiveness of different systems can vary greatly. For example, some air cleaners can emit pollutants (e.g. ozone), stand alone units can be ineffective, and some of the less expensive models are almost worthless.

- o Air cleaning and/or ventilation cannot be relied upon as a sole control strategy for ETS.

- o Control strategies involving source control, ventilation control, and air cleaning should be integrated into the building design, operation and maintenance procedures.

- o Standardized protocols for investigating and solving indoor air quality problems need to be developed and widely promulgated.

In addition to the engineering and operational control of indoor air, Volume II discusses various administrative control options that are available, considerations in choosing among those options, and the available legislative authorities, policies and programs used to implement controls.

Chapter 7 presents available air quality and ventilation standards and evaluates their applicability to indoor air problems.

Chapter 8 summarizes federal legislative authority of the major federal agencies with responsibility for indoor air, and Chapter 9 summarizes available control programs in the public and private sector. This material suggests the following:

- o The Clean Air Act cannot be used to regulate the quality of the air indoors.

- o Many Federal agencies have the explicit legal authority to regulate products and/or activities that affect indoor air quality, or to regulate the quality of the air in specific indoor environments. Existing authority ranges from the ability to ban or restrict the use of pesticides and consumer products to setting and enforcing occupational indoor air quality standards in occupational settings. However, these authorities are fragmented, are limited to specific products or environments, and some address indoor air quality concerns secondarily or only implicitly.

- o Most legal authority related specifically to building systems rests with the Department of Energy, and is directed toward energy conservation, with indoor air as a secondary concern.

- o SARA Title IV provides EPA with direct indoor air authority to conduct a research, coordination, and information dissemination program, but does not enhance EPA's regulatory authority with respect to indoor air quality beyond existing authorities under TSCA, FIFRA, and the Safe Drinking Water Act.

- Significant potential exists for cooperative coordinated indoor air control programs at the Federal, state and local governmental levels, and in the private sector. Currently, coordination is achieved informally through professional associations, voluntary standards organizations, and the Federal Interagency Committee on Indoor Air Quality. Current programs at all levels of government and the private sector are generally fragmented and underfunded.

Chapter 10 discusses the type of policy options that might be considered as indoor air programs in the Federal government are initiated and expanded. Because of the variety of indoor air pollution sources and control measures and the many types of indoor environments, many policy options are available. Some of these options can be implemented either as enforceable regulations or as recommended guidance. Some options focus on reducing levels of individual pollutants and are thus often referred to as "pollutant-by-pollutant" strategies; others focus on reducing levels of many pollutants simultaneously and are thus often referred to as "multi-pollutant" strategies. The policy options described in this chapter include:

- Developing public information and technical assistance programs which assist the private sector, including homeowners and building owners/operators, in achieving acceptable indoor air quality.

- Establishing pollutant-specific enforceable standards or voluntary guidelines.

- Establishing enforceable ventilation standards or voluntary ventilation guidelines.

- Stepping up development of voluntary or mandatory standards for products or activities that affect indoor air quality.

- Providing guidance on identifying and correcting indoor air quality problems in existing buildings.

- Providing guidance on preventing indoor air quality problems in new buildings.

SUMMARY OF VOLUME III -- INDOOR AIR RESEARCH NEEDS

Volume III of the report sets forth the research needs which must be met through the combined efforts of the public and private sectors to adequately characterize and develop effective mitigation strategies for dealing with indoor air quality issues. Volume III was prepared by an interagency workgroup of the CIAQ under the sponsorship of EPA's Office of Research and Development. The major indoor air research needs are categorized as follows:

- Risk assessment methods. This category includes health and hazard identification, dose-response assessment, exposure assessment, and risk characterization frameworks and methods.

- Exposure assessment and modeling needs. This category includes methods development and evaluation, measurement studies, development of predictive models and the management of measurement data.

- Source-specific needs. This category includes research needed regarding specific indoor air pollution sources. Indoor combustion sources such as tobacco products and indoor combustion appliances, building materials and furnishings, activity sources that emphasize product use and storage, ambient sources of urban pollutants, and biological contaminants are examples of the source category.

- Control techniques. This category includes evaluation of techniques aimed at controlling specific sources of indoor pollutants and examining the effectiveness of ventilation strategies.

- Building system needs. This category includes studies of infiltration and ventilation in both large and small buildings; field measurements in complaint and non-complaint buildings; and research devoted to building system design.

- Technology transfer. This category includes programs to transfer research results to users in the public and private sectors.

A Table summarizing the major indoor air research needs, including relative priorities, is appended to this Executive Summary.

SUMMARY OF MAJOR INDOOR AIR RESEARCH NEEDS[1]

RESEARCH AREA AND STUDY DESCRIPTION	AGENCIES AND ORGANIZATIONS INVOLVED	PROJECT TIME (YRS)	PRIORITY[2]
A. RISK ASSESSMENT METHODOLOGY FRAMEWORK			
1. Risk Assessment Methods			
* Develop risk methodology procedures and perform assessments for major indoor air pollution scenarios, and conduct additional toxicological research vis-a-vis evaluation of respiratory hazards	EPA/CPSC/DHHS/ STATES/PRIVATE SECTOR	4	PRIMARY
2. Special Reports and Hazard Identification			
* Prepare special reports evaluating biological contaminants, odors and annoyance levels, and the effects of cleaning and maintenance on indoor air quality	EPA/CPSC/DHHS/ DOE/PRIVATE SECTOR	5	SECONDARY
3. Supporting Information for Risk Assessment			
* Provide support for development and maintenance of data bases	EPA/DHHS/DOE/PRIVATE SECTOR	5	PRIMARY
B. EXPOSURE ASSESSMENT AND MODELING			
1. Monitoring and Measurement			
* Improve sampling and analytical techniques for volatile and semi-volatile organic compounds	EPA/DHHS/DOE/NIST	4	PRIMARY
* Develop improved screening protocols, questionnaires, and measurement methods for complaint-building studies	EPA/DHHS/DOE/STATES	4	PRIMARY
* Develop improved screening protocols, questionnaires, and measurement methods for indoor air quality studies in residences	EPA/CPSC/PRIVATE SECTOR	4	SECONDARY
* Evaluate and validate new measurement methodologies under field conditions for aerosols, organics, biological species, and air exchange rates	EPA/CPSC/DHHS/DOE/ PRIVATE SECTOR	4	PRIMARY
* Develop validation procedures to improve accuracy of information collection (such as questionnaires and activity diaries)	EPA/DHHS/DOE/PRIVATE SECTOR	4	SECONDARY
2. Modeling			
* Further develop and validate spatial/temporal models, source models, receptor models, and exposure models for indoor environments including transportation compartments	EPA/CPSC/DHHS/DOE/ STATES/PRIVATE SECTOR	5	SECONDARY

[1]Research needs to be conducted by both the public and private sectors.
[2]Primary research projects are those projects that need to be initiated immediately to provide important information to protect public health or to begin more in-depth research. Secondary status research projects are also necessary projects that will begin after an evaluation of preliminary research results, or as soon as research facilities, staff and funding become available.

SUMMARY OF MAJOR INDOOR AIR RESEARCH NEEDS[1] (continued)

RESEARCH AREA AND STUDY DESCRIPTION	AGENCIES AND ORGANIZATIONS INVOLVED	PROJECT TIME (YRS)	PRIORITY[2]
3. Data Management and Quality Assurance			
* Implement and maintain a source emissions data base incorporating source characteristics associated with emission factors	EPA/CPSC	5	PRIMARY
* Develop standard reference materials for measurement of indoor pollutants	NIST/EPA	5	PRIMARY
* Implement and maintain an indoor air quality data repository	EPA/CPSC/DHHS/DOE/ STATES/PRIVATE SECTOR	5	PRIMARY
C. SOURCE-SPECIFIC NEEDS			
1. Combustion Sources			
Environmental Tobacco Smoke (ETS)			
* Characterize and model ETS exposure to children	DHHS/EPA	2	PRIMARY
* Develop ETS exposure dosimetry methods	DHHS/EPA	2	PRIMARY
* Evaluate cancer risks from ETS exposure	DHHS/EPA	3	PRIMARY
* Study the non-cancer effects from ETS exposure	DHHS/EPA	4	PRIMARY
Indoor Combustion Appliances			
* Characterize emissions from kerosene heaters	CPSC/EPA/PRIVATE SECTOR	3	PRIMARY
* Prepare exposure assessment of kerosene heater, gas-space heater, wood stove, and unvented gas stove emissions	CPSC/EPA/PRIVATE SECTOR	4	PRIMARY
* Dosimetry - Develop physiologically-based dose-response models and biological markers	EPA/DHHS/PRIVATE SECTOR	4	SECONDARY
* Cancer risks - Conduct epidemiology feasibility study and perform in vitro and in vivo genetic and carcinogenic bioassays	EPA/DHHS/STATES	4	SECONDARY
* Non-cancer health risks - Prepare screening studies for hazard identification, multidisciplinary assessments, and verify the accuracy of the predictive exposure, dose, and health effects models	EPA/DHHS/STATES PRIVATE SECTOR	5	SECONDARY
2. Material Sources			
* Measure emission rates of organic chemicals from building materials, furnishings, and consumer products	EPA/CPSC/DOE	3	PRIMARY
* Conduct comparisons of emissions from selected materials in small chambers, large chambers, and test houses	EPA/CPSC/PRIVATE SECTOR	3	PRIMARY
* Characterize the human response produced by emissions from selected materials	EPA/DHHS/STATES	5	PRIMARY
* Evaluate health effects of substitute products and materials	EPA/DHHS	3	PRIMARY

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SUMMARY OF MAJOR INDOOR AIR RESEARCH NEEDS[1] (continued)

RESEARCH AREA AND STUDY DESCRIPTION	AGENCIES AND ORGANIZATIONS INVOLVED	PROJECT TIME (YRS)	PRIORITY[2]
3. Activity Sources			
* Develop measurement methods and generate emission factors for activities associated with personal care, maintenance, office work, leisure, and transportation	EPA/CPSC/DHHS	5	PRIMARY
* Characterize electrical, magnetic, and electromagnetic fields encountered in personal and work-related activities	DOE/DHHS/EPA/PRIVATE SECTOR	5	SECONDARY
* Determine the health effects and mechanisms of interaction with electromagnetic fields	DOE/DHHS/EPA/PRIVATE SECTOR	5	SECONDARY
* Characterize indoor exposures to consumer-applied pesticides (and other toxicants)	EPA/PRIVATE SECTOR	5	PRIMARY
4. Ambient Sources			
Outdoor Air			
* Characterize indoor/outdoor concentration relationships for input to exposure models (e.g., heavy metals, ozone, and biological contaminants)	EPA/DHHS/STATES	5	SECONDARY
Soil			
* Characterize the penetration of soil-related pollutants into the indoor environment and perform a risk assessment	EPA/STATES	3	SECONDARY
Water			
* Characterize exposures to volatile organic compounds released from water	EPA	3	SECONDARY
* Investigate contribution of tap water in home humidifiers to indoor pollutant levels	EPA/CPSC	3	PRIMARY
5. Biological Contaminants			
* Prepare report on health effects, state-of-the-art sampling methods, and research needs	EPA/CPSC/DHHS/PRIVATE SECTOR	2	PRIMARY
* Initiate development of standardized monitoring methods	EPA/CPSC/DHHS/PRIVATE SECTOR	3	PRIMARY
* Hardware development for biological monitoring methods	EPA/CPSC/DHHS/PRIVATE SECTOR	2	SECONDARY
* Identify and establish baseline concentrations of major classes of biological contaminants	EPA/CPSC/DHHS/PRIVATE SECTOR	4	PRIMARY
* Investigate contribution of HVAC equipment to indoor levels of biologicals	EPA/CPSC/DHHS/DOE/ STATES/PRIVATE SECTOR	4	PRIMARY

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SUMMARY OF MAJOR INDOOR AIR RESEARCH NEEDS[1] (continued)

RESEARCH AREA AND STUDY DESCRIPTION	AGENCIES AND ORGANIZATIONS INVOLVED	PROJECT TIME (YRS)	PRIORITY[2]
D. CONTROL TECHNIQUES			
1. Source-Specific			
* Evaluate effectiveness of source modifications, including changes in product composition or use, conditioning of building materials before use, and product substitution	EPA/CPSC/DOE/STATES/ PRIVATE SECTOR	5	PRIMARY
2. Air Cleaning			
* Conduct laboratory and field studies to determine the effectiveness of air cleaners for the control of indoor pollutants	EPA/CPSC/DOE/NIST/ PRIVATE SECTOR	3	PRIMARY
E. BUILDING SYSTEMS			
1. Ventilation			
* Continue research to refine tracer gas techniques for measuring ventilation	DOE/DHHS/EPA/NIST/ PRIVATE SECTOR	3	SECONDARY
* Develop ventilation measurements that can be widely applied	EPA/DOE/DHHS/NIST/ PRIVATE SECTOR	4	PRIMARY
* Continue research devoted to laboratory measurements of ventilation	DOE/EPA/PRIVATE SECTOR	4	SECONDARY
* Develop techniques and protocols to measure ventilation effectiveness	NIST/EPA/DOE/DHHS/ PRIVATE SECTOR	5	PRIMARY
2. Field Measurements			
* Measure ventilation rates and ventilation effectiveness in complaint-building investigations and residences	EPA/CPSC/DHHS/DOE/ NIST/PRIVATE SECTOR	5	PRIMARY
3. The Total Building System			
* Conduct prototype integrated assessments of the combined impacts of source emissions, pollutant levels, ventilation rates, and energy consumption in new building designs and perform follow-up measurements	EPA/CPSC/DHHS/DOE/ NIST/PRIVATE SECTOR	5	PRIMARY

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SUMMARY OF MAJOR INDOOR AIR RESEARCH NEEDS[1] (continued)

RESEARCH AREA AND STUDY DESCRIPTION	AGENCIES AND ORGANIZATIONS INVOLVED	PROJECT TIME (YRS)	PRIORITY[2]
F. CROSSCUTTING RESEARCH			
* Conduct an epidemiologic study of the impact of indoor air quality on productivity	EPA/CPSC/DHHS/DOE/ NIST/STATES/ PRIVATE SECTOR	3	PRIMARY
* Conduct studies regarding the prevalence of building-occupant symptoms and indoor pollutant levels	DHHS/EPA/STATES/ PRIVATE SECTOR	4	SECONDARY
* Conduct ergonomic and psychosocial research	DHHS/EPA/PRIVATE	3	SECONDARY
G. TECHNOLOGY TRANSFER	FEDERAL AGENCIES/STATES/ PRIVATE SECTOR		PRIMARY

[1]Research needs to be conducted by both the public and private sectors.
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